II. Remarks

Reconsideration and allowance of the subject application are respectfully requested.

Claims 29-38 and 43 are pending in the application. Claim 29 is independent. Claims 29-31 and 33-38 have been amended herein. Claim 43 has been added. With respect to Claim 29, support for the amendment may be found at least at paragraph 0037. With respect to Claim 31, support for the amendment may be found at least at paragraph 0027, at paragraph 0069, and in Figure 4. With respect to new Claim 43, support for this claim may be found at least at paragraphs 0038 – 0061 and in Figure 8. Accordingly, no new matter has been added.

Claim 32 stands rejected under 35 U.S.C. § 112, second paragraph, as allegedly being indefinite for failing to particularly point out and distinctly claim the subject matter which applicant regards as the invention. Specifically, at page 5 of the January 26 Office Action, it is alleged that the term "said desired transception-quality" lacks a sufficient antecedent basis. As amended, independent Claim 29 recites that "said antenna transceives a radio link in a direction that achieves a desired transception-quality over said link". Claim 32 depends from Claim 29. Accordingly, Applicant submits that all elements of Claim 29 have sufficient antecedent basis, and therefore requests that this rejection be withdrawn.

At page 5 of the January 26 Office Action, it is noted that "the word 'transception' does not appear in the dictionary", and it is suggested that the word "transception" be replaced by the word "signal". Applicant respectfully points out that

the term "transception" is defined as "transmission and/or reception", and that this meaning is made clear in the specification at least at paragraphs 0027, 0037, and 0045. Further, Applicant points out that the term "transception" appears in numerous U.S. patents, including U.S. Patents Nos. 6,791,158; 6,032,020; and 5,710,809. Accordingly, Applicant respectfully declines to delete the recited claim term "transception".

Claims 29-31, 34, 36, and 37 stand rejected under 35 U.S.C. § 102(e) as being anticipated by U.S. Patent No. 6,606,059 to Barabash ("Barabash"). Claims 33 and 38 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over Barabash in view of U.S. Published Patent Application No. US 2004/0235527 to Reudink, et al. ("Reudink"). Claim 35 stands rejected under 35 U.S.C. § 103(a) as being unpatentable over Barabash in view of U.S. Patent No. 6,014,144 to Westfall, et al. ("Westfall"). These rejections are traversed.

As amended, independent Claim 29 recites an antenna for a wireless local loop subscriber station. The antenna includes: a connecting means for attaching said antenna to a radio of said subscriber station; and a plurality of directional antennas each defining a different sector of coverage for said antenna. Each of said directional antennas has a coupled patch configuration and is switchable in relation to each other such that said antenna transceives a radio link in a direction that achieves a desired transception-quality over said link.

At page 2 of the Office Action, it is stated that "Barabash teaches that the steerable antenna includes four directional antennas at an angle of ninety degrees to

the other, each of the directional antennas having a coupled patch configuration". However, Applicant submits that Barabash fails to disclose any antennas that have a coupled patch configuration. Rather, Barabash discloses a patch antenna. For example, at column 5, lines 46-48 of Barabash, the following text that describes Figures 4A-4C appears: "The antenna 100 is preferably constructed in accordance with the structure of a patch antenna." As another example, at column 6, lines 20-22 of Barabash, the following text appears: "Together, the tubular body 102, the ground plane material 104 and the radiating elements 106, 108, 110, and 112, form the three main components of a patch antenna system." By contrast, there is no disclosure in Barabash of a "coupled patch" antenna configuration.

There is a significant distinction between a patch antenna and a coupled patch antenna configuration. To assist in explaining this distinction, and for the convenience of the Examiner, Applicant has attached a copy of a journal article entitled "An Experimental Investigation of a Short Backfire Antenna with Electromagnetic Coupled Patch as Feed Element" by Taqi, et al. This article is also being cited as a reference in a Supplemental Information Disclosure Statement accompanying this Amendment.

As explained in the Taqi article, "[a] basic microstrip patch antenna is a thin conducting strip radiator of different shapes separated from its grounded plane by a thin layer of dielectric substrate". Such a patch antenna tends to have an intrinsically narrow bandwidth and limited gain. By contrast, a coupled patch antenna configuration is a combination of two patch antennas that have been electromagnetically coupled to

one another in order to increase the bandwidth and/or the gain. Such a coupling may be achieved, for example, by aligning the two patch antennas so that their centers are along a common axis, and so that the separation between the two is chosen in order to maximize the bandwidth.

Accordingly, because a coupled patch antenna configuration differs significantly from a patch antenna, and because Barabash fails to disclose a coupled patch antenna configuration, as recited in independent Claim 29, Applicant submits that independent Claim 29 is allowable over Barabash for at least this reason. Furthermore, because each of Claims 30-38 and 43 depends from independent Claim 29, each of these dependent claims is also allowable over Barabash for the same reason as described above with respect to Claim 29.

In view of the above amendments and remarks, it is believed that this application is now in condition for allowance, and a Notice thereof is respectfully requested.

Applicant's attorney may be reached in our Washington, D.C. office by telephone at (202) 625-3500. All correspondence should continue to be directed to our address given below.

Respectfully submitted,

James A. Gromada

Attorney for Applicant
James A. Gromada
Registration No. 44,727

PATENT ADMINISTRATOR
KATTEN MUCHIN ROSENMAN L.L.P.
525 West Monroe Street
Chicago, Illinois 60661-3693
Facsimile: (312) 902-1061

Journal of
Islamic Academy of Sciences
Volume 8, No.2

Back to Journal of IAS, Volume 8, No 2, 1995.

An Experimental Investigation of a Short Backfire Antenna with Electromagnetic Coupled Patch as Feed Element

A. H. TAQI*, R. A. AL-RASHID*, A. M. JASSIM**

* From Department of Physics, College of Science, Saddam University, Baghdad, Iraq.
** From Space Research Center, Baghdad, Iraq.

SUMMARY: *In this paper a short backfire antenna fed by an electromagnetic coupled patch (EMCP) operating at X-band is constructed and its performance is experimentally investigated and reported. The antenna is excited in the* TM_{10}*-mode. The resonant frequency is also measured and its value is compared with the predicted values as a mutual check of the experimental data. The experimental results indicate a remarkable improvement in the radiation pattern as well as in the gain and a noticeable increment in the bandwidth of the backfire antenna as compared with those of a single patch microstrip radiator.*

Key Words: Backfire antenna, electromagnetic coupled patch feed element.

INTRODUCTION

Over the past twenty five years microstrip resonators have been widely used in the range of microwave frequencies. In general these structures are poor radiators, but by proper design the radiation performance can be improved and these structures can be used as antenna elements (1-6). In recent years microstrip patch antennas became one of the most popular antenna types for use in aerospace vehicles, telemetry and satellite communication, since they are light weight, inexpensive, easily manufactured and have simple geometry, flat profile. They can be simply integrated with solid state devices.

A basic microstrip patch antenna is a thin conducting strip radiator of different shapes separated from its grounded plane by a thin layer of dielectric substrate. There are two main restriction of use of a single patch microstrip antenna, namely, its intrinsic narrow bandwidth and its limited gain. The bandwidth of a single patch microstrip antenna does not exceed 2% and its gain is limited to (5-8) dB. In recent years, several techniques have been attempted to increase the bandwidth of the antenna or to boost its gain. One effective method to overcome these two problems is to add a second patch in front of the initial one resulting in a so called dual-patch microstrip antenna. The concept of stacking patches in a backfire form, to enhance the gain or in an electromagnetic-coupling form to increase the bandwidth have been treated

by several authors (7-14).

This paper represents an experimental study of the performance of the two types of dual patch microstrip antennas. These are an electromagnetically coupled patch (EMCP) antenna with a single square patch-feed excited in the TM_{10}-mode, operating in the X-band region and a backfire antenna with the EMCP as feed element. The experimental results obtained indicate a significant improvement in the radiation characteristics as well as in the gain and a noticeable increment in the bandwidth of the backfire antenna as compared to those of a single patch microstrip antenna.

ANTENNA DESIGN

a) The single patch microstrip antenna:
The design of a single square microstrip antenna operating in the TM_{10}-mode implies that the patch side taking into account the fringing effect, should be chosen slightly less than $\lambda d/2$ where λd is the wavelength in the substrate. The single patch microstrip antenna investigated is designed to operate at a resonant frequency of about 9 GHz. Accordingly the antenna consists of a square patch of a side a=8.8 mm. The patch is fabricated on a dielectric substrate of thickness h=1.6 mm and of relative permittivity of ε_r=2.5. The patch was fed an SMA-coaxial feed located at the midpoint of the edge of the patch. The patch and the substrate are supported on a 9 cm x 9 cm grounded copper plate.

b) The electromagnetic-coupled patch (EMCP) antenna:
A second patch is added and the two patches were photo-etched on separate substrates and aligned so that their centers are long the common axis. The size of the second patch and the separation between the two patches were adjusted to obtain maximum bandwidth. The first patch is referred to as feeding patch (P_f) and the second patch is the radiating patch (P_r).

c) The backfire antenna with the EMCP as feed element:
The EMCP with optimum dimensions is used as feed element to excite the backfire antenna. A small square reflector is placed at a distance d' from the second patch with its center a long the common axis of the antenna. The ground plane serves as large back reflector for the backfire antenna. Different sizes of small front reflectors were tried. The one with optimum size was used in the final design of the antenna. The spacing between the small reflector and the radiating patch is provided with a facility for optimum adjustment. The final shape of the backfire antenna with its optimum dimensions is illustrated in Figure 1.

RESULTS

Resonant Frequency and Input Impedance

The resonant frequency of an electrically thin microstrip antenna is defined as the frequency at which the imaginary part of the input impedance is equal to zero. But for electrically thick microstrip antennas, which is the case in this investigation, the reactance curve never passes through zero, because of the inductive shift of the coaxial feed, and for this reason the resonant frequency is defined as that frequency at which the input resistance reaches its maximum value (15). Using an HP 8510 automatic network analyzer the measured resonant frequency of the single patch antenna was found to be 8.9 GHz and the measured input

resistance at resonance was 548 Ω. The input impedance locus and the input impedance as a function of frequency for the single patch antenna are shown in the Figure 2. The calculated value of the resonant frequency for the single patch excited with the TM_{10}-mode if there were no fringing effect is given by (6,15)

$$f_r = \frac{c}{2a\sqrt{\varepsilon_r}} \quad (1)$$

where c is the velocity of light in free space. However, in practice the fringing effect causes the effective distance between the radiating edges of the patch to be slightly greater than a, therefore the actual value of the resonant frequency is slightly less than f_r. Taking into account the effect of the fringing field two predicted formulas proposed by Hammerstadt (15) and by James *et. al.* (16) were used to calculate the resonant frequencies of the single patch antenna. The calculated frequency values using these two methods were 9.17 GHz and 8.78 GHz respectively.

The resonant frequency and the resonant input resistance were measured for the EMCP antenna with different sizes of the radiating patch for different separation between the two patches. The results are illustrated in Table 1. The input impedance loci of the EMCP antenna for different separations between the two patches and for different sizes of the second patch are given in Figure 3 and 4 respectively.

The Gain

The directive gain of the three antenna types were measured using a pyramidal horn of gain 16.7 dB as a standard antenna. The gain of the single patch antenna was found to be 5.3 dB. The gain of the EMCP antenna was measured for patches of equal size of 8.8 mm on a side with different positions of the second patch with respect to the basic patch. The results are tabulated in Table 2. Inspection of Table 2, taking into account the best value for the bandwidth, indicate that the maximum value of the directive gain is 8.7 dB. This is an improvement of 3.4 dB above that of a single patch antenna. The gain of the backfire antenna was measured for different sizes of front reflector and different separations d" between front reflector and the ground plane. The best result was for a small reflector of size equal to those for the two patches and with a separation d"=3.33 cm ($\approx\lambda_0$). The maximum gain for the backfire antenna was 12.5 dB with an increment of 7.2 dB above that for the single patch antenna. More increment in the gain can be achieved by adding more front reflectors.

The gain of the backfire antenna was calculated as a mutual check of the experimental results using the following relation (10).

$$G(dB) = 10\log\frac{2600}{\Theta^{\circ}_E\Theta^{\circ}_H} \quad (2)$$

where Θ°_E and Θ°_H are the beamwidth of the half power points in the E-plane and H-plane respectively. The gain was found to be 12.1 dB which is 0.4 dB less than the measured value.

The Power Pattern

The measured radiation pattern of the three antenna types for optimum dimensions at resonant frequency in both E-plane and H-plane are illustrated in Figures 5a and b respectively. Inspection of these two figures shows the effect of applying the backfire principle on the shape of the pattern in both E-plane and H-plane. The shape of the pattern is smooth with narrow beamwidth and very low side lobs and it is symmetrical in both E-plane and H-plane for the backfire antenna, whilst it is rough with broad beamwidth and too many high side lobs and is non-symmetrical in both planes for single patch and EMCP antennas.

The cross-polar pattern for the backfire antenna was also measured. Its level was better than 15.5 dB in the E-plane and 18 dB in the H-plane, this is also shown in Figure 5. The power radiation patterns of the backfire antenna with the EMCP in E-plane and H-plane at different frequencies are shown in Figures 6a and b respectively. Figure 7 shows the influence of adding a rim of width w=10 mm to the periphery of the ground plane of the backfire antenna on the radiation pattern at resonant frequency in both the E-plane and the H-plane. This figure, indicates some improvement in the beamwidth in the E-plane pattern. This improvement can be seen as an increment in the directive gain. Table 3 gives a comparison summary for the performance of the single patch, the EMCP and for backfire antenna with the EMCP as feed.

The Bandwidth

The input impedance was calculated as a function of frequency for the single patch as well as for the EMCP antennas. Following the resonant circuit model mentioned in (15) the percentage bandwidth for the single patch antenna was calculated as 1%. The same method was used to calculate the percentage bandwidth for the EMCP antenna for different sizes of the second patch and patch to patch distances. The results are shown in the Table 1 and 2 respectively. The best result was for the EMCP with the second patch of dimensions of 8.8 mm x 8.8 mm and patch to patch separation of s = 3.36 mm. The bandwidth was 11.1%. It is an excellent improvement in the bandwidth compared with that of a single patch antenna. No more improvement in the bandwidth was noticed by applying the backfire principle.

CONCLUSION

In this study it has been shown that the bandwidth of a conventional square microstrip patch antenna excited in the TM_{10}-mode operating in the X-band region can be improved by applying the electromagnetic coupled principle. The backfire principle was used to improved the electrical characteristics as well as the gain of the antenna. For this purpose the EMCP was used to excite the backfire antenna. The reported results indicate that the backfire antenna has higher directive gain broader bandwidth and symmetrical radiation pattern with narrow beamwidth and lower side lobes level in both the E-plane and the H-plane when compared to those of a single patch antenna. This backfire antenna is compact, light weight, inexpensive and has small size. It can be used as feed element in reflector antennas for communication purposes.

REFERENCES

1. Munson RE : Conformal microstrip antennas and microstrip phased arrays. IEEE Transaction on Antennas and Propagation, AP-22, pp 74-78, 1974.

2. Howell JQ : Microstrip antennas. IEEE Transaction on Antennas and Propagation, pp 90-93, 1975.

3. Agrawal PK and Baily MC : An analysis technique for microstrip antennas. IEEE Transaction on Antennas and Propagation, pp 756-759, 1977

4. Lo YT, Solomon D and Richards WF : Theory and experiment on microstrip antennas. IEEE Transaction on Antennas and Propagation, AP-27, No 2, March, 1979.

5. Hammer P, Van Bauchaute D, Vershraeven D and Van de Capellev : A model for calculating the radiation of microstrip antenna. IEEE Transaction on Antennas and Propagation, No 2, pp 267-273, March, 1975.

6. Carver KR and Mink JW : Microstrip antenna technology. IEEE Transaction on Antenna and Propagation, No 1, pp 1-24, Jan, 1981.

7. Vandenbosch G and Van de Capelle A : A highly Accurate feed model for microstrip backfire antenna. Radio Science, No 2, pp 571-577, March-April, 1991.

8. Vandenbosch Guy AE and Van de Cappele A R : Theoretical study of the rectangular microstrip backfire antenna. AEU International Journal of Electronics Communications, No 3, pp 162-166, 1993.

9. Zhong Shun-Shi and Zhi-Dian Chen : Two-layer patch backfire antenna. IEEE AP-S Int Symp Dig, pp 1611-1614, 1991.

10. Lee RQ and Lee KF : Parasitic size and superstrate effects on electromagnetically coupled rectangular patch antenna. Electronic Lett, Vol 23, No 20, pp 1070-1072, 1987.

11. Lee RQ and Lee KF : Parasitic size and superstrate effects on electromagnetic coupled patch antenna. Electromagnetic, Vol 9, pp 395-404, 1989.

12. Kaloi CM, Hatfield D and Simon P : Microstrip backfire antenna. IEEE AP-S, Int Sym Digest, pp 343-346, 1981.

13. Sabbon A : A new broad band stacked two-layer microstrip antenna. IEEE-S, International Sympossium Digest, pp 63-66, 1983.

14. Bhatnagar PS, Daniel J, Mahdioubi K and Terret C : Experimental study on stacked triangular microstrip antenna. Electron lett, pp 864-865, 1986.

15. Chang Esing, Stuara Along and William F Richards : An experimental investigation of electrically thick rectangular microstrip Antenna. IEEE transactions on antennas and propagation, No 6, pp 767-772, June, 1986

16. James JR, Hall PS and Hall S : Microstrip antenna theory and design. Peter Peregrinus Ltd, London and New York, 1981.

17. James JR and Hall PS : Handbook of microstrip antennas. Peter Peregrinus Ltd, London and New York, 1989.

18. Bahl IJ and Bhartia P : Microstrip Antennas. Artech House, Inc printed and bound in the USA, 1980.

19. Lee KF, Lee RQ and Talty T : Microstrip subarry with coplanar and stacked parasitic elements. Elec Letters, No 10, pp 668-669, May, 1990.

Correspondence

R. A. Al-Rashid
Department of Physics,
College of Science,
Saddam University,
Jadiriya, Baghdad, IRAQ.

Back to Journal of IAS, Volume 8, No 2, 1995.
